Lost in Transit: Product Replacement Bias and Pricing to Market

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Prices and Exchange Rates

Conventional wisdom for post-Bretton Woods period:

- Large swings in U.S. dollar exchange rate
- U.S. import and export prices more stable
- Measured pass-through:
  - Prices of U.S. imports: 0.2-0.4%
  - Prices of U.S. exports: 0.9%
- Exchange rate disconnect “puzzle”

Prices and Exchange Rates

$$p_t^m - p_t = \alpha + \gamma t - \beta q_t + \epsilon_t$$

- Leading potential explanation: Pricing to market
  - Exporters "price to market" if they adjust the markups to stabilize the local currency price of their products (Krugman, 1987)
- Not necessarily a causal relationship
- Semantics: Pricing to Market = 1 - Pass-Through

Prices and Exchange Rates: Models

- Simple models: No pricing to market
  - Backus, Kehoe and Kydland (1992), Stockman and Tesar (1995), Obstfeld and Rogoff (1995)
- Models with long run pricing to market:
  - Dornbusch (1987), Goldberg and Verboven (2001), Corsetti and Dedola (2005), Atkeson and Burstein (2008), Gust, Leduc and Vigfusson (2006), Gopinath, Itskhoki and Rigobon (2007), Drozd and Nosal (2008).

Prices and Exchange Rates: Policy

- Pricing to market has profound policy implications
- Traditional view:
  - Flexible exchange rate generates expenditure switching
  - Depreciation yields increased “competitiveness”
- Pricing to market shuts down this pathway
  - Firms stabilize their prices in local currency terms
  - Domestic production doesn’t become cheaper

Prices and Exchange Rates: Puzzles

Estimates of U.S. pricing to market raise theoretical challenges:

1. Difficult to match measured pricing to market for imports
   - Large markups to avoid negative profits
   - Large strategic complementarities
   - Existing models:

     Atkeson and Burstein (2008): 0.75

     Corsetti and Dedola (2005): 0.9
2. Why such a large asymmetry between U.S. imports and exports?
3. Why is the U.S. such an outlier?

Import and Export Price Data

1. Product replacement is frequent
2. Measured prices are sticky

- Few price changes per product:

  45% have none

  70% have 2 or less

Measurement

What happens to prices at the time of product replacements?

- Difficult to measure
- In practice: Many product replacements are “linked in”
  - Inflation measured as inflation for continuing goods
- New goods bias:
  - Upward bias in the level of measured inflation
- Product replacement bias:
  - Downward bias in responsiveness to real exchange rates

Price Index Measurement

Fixed Weight Tornqvist index:

$$\Delta P_{it} = \sum_{j=1}^{N} w_j \Delta p_{jit}$$

ΔP_{it}: Log change in aggregate price index

Δp_{jit}: Log change in price of product j

w_j: Expenditure weight

- Matched model index: inflation for continuing goods
- Price changes for new goods are dropped (unobserved)

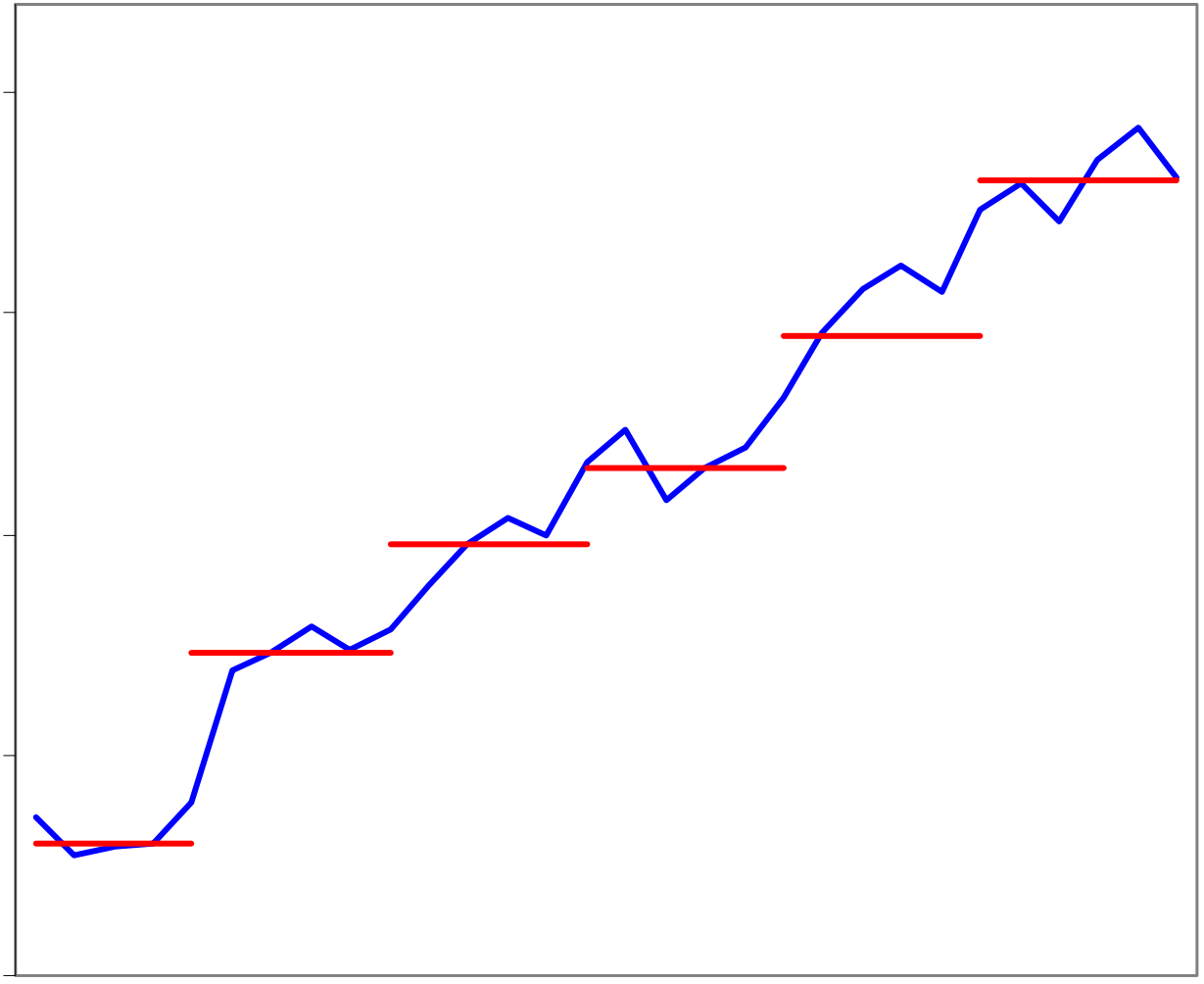

Figure: Prices and Exchange Rates

Alternative Assumption

Prices are reset (fresh) at time of product replacements

- Firms set new prices when buyer, seller or product specification changes
- Measurement issues

Objectives

This paper:

- Quantify magnitude of product replacement bias using estimates of the frequency of price change and product replacement
- Test other predictions of model with product replacement bias

Preview of Results

- Product replacement bias:
  - Roughly a factor of 2
- Revised estimates of pass-through:
  - Imports: 0.7 (rather than 0.4)
  - Exports: 0.8 (rather than 0.9)
- Pricing to market:
  - More symmetric
  - More moderate for imports
- Implies more volatile terms of trade
- Improves fit of data to standard models

Overview

- Pass-through regressions (aggregate data)
- Theoretical factor calculation
- Measurement of product replacement bias (micro data)
- Alternative measures of pass-through (micro data)

Data

- NIPA price indices on import and export prices 1982 - 2007
- Fed real exchange rate series (Major Currency)

Prices and Exchange Rates: Evidence

- Simple measure of pricing to market:

$$p_t^m - p_t = \alpha + \gamma t - \beta q_t + \epsilon_t$$

$p_t^m - p_t$: Relative price of foreign products

q_t: Real exchange rate (home price relative to foreign price)

Prices and Exchange Rates: Evidence

VECM:

$$\Delta y_t = \Pi(A y_{t-1} + \alpha + \gamma t) + \sum_{k=1}^{n-1} \Gamma_k \Delta y_{t-k} + \delta + \epsilon_t$$

- $y_t = (p_t^m - p_t,\ q_t)$
- Coefficients in cointegrating vector: [1 β]

Dynamic adjustment:

$$\Delta(p_t^m - p_t) = \alpha - \sum_{k=0}^{6} \beta_k \Delta q_{t-k} + \epsilon_t$$

Note: Pricing to market = 1- pass-through for aggregate data

TABLE
Pricing to Market

	Imports	Exports
Measured:		
VECM	0.41	0.87
	(0.05)	(0.06)
Dynamic Adjustment	0.43	0.85
	(0.05)	(0.05)
Levels	0.36	0.86
	(0.02)	(0.03)

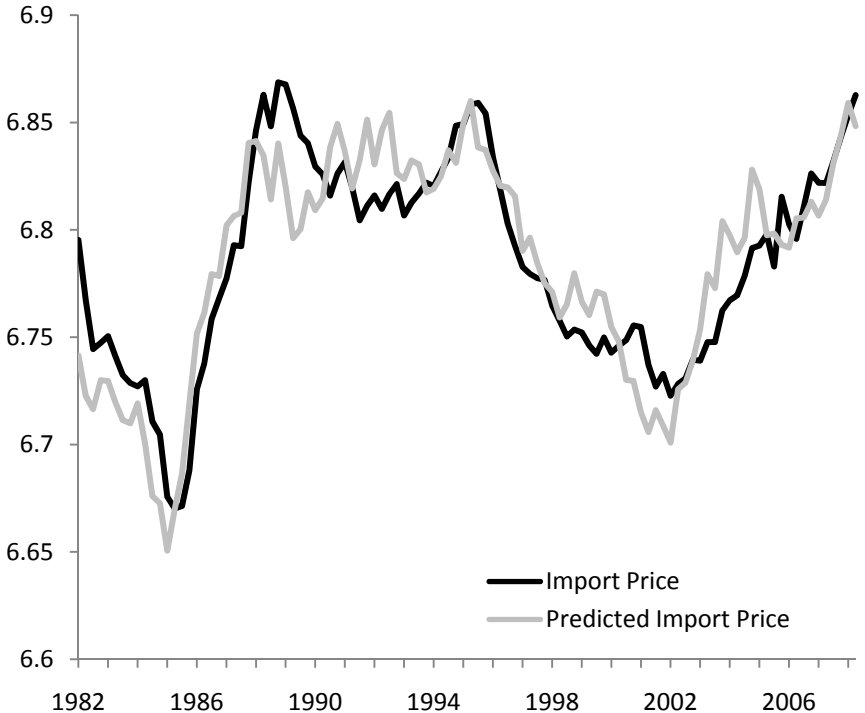

Figure II
U.S. Import Prices and the Real Exchange Rate

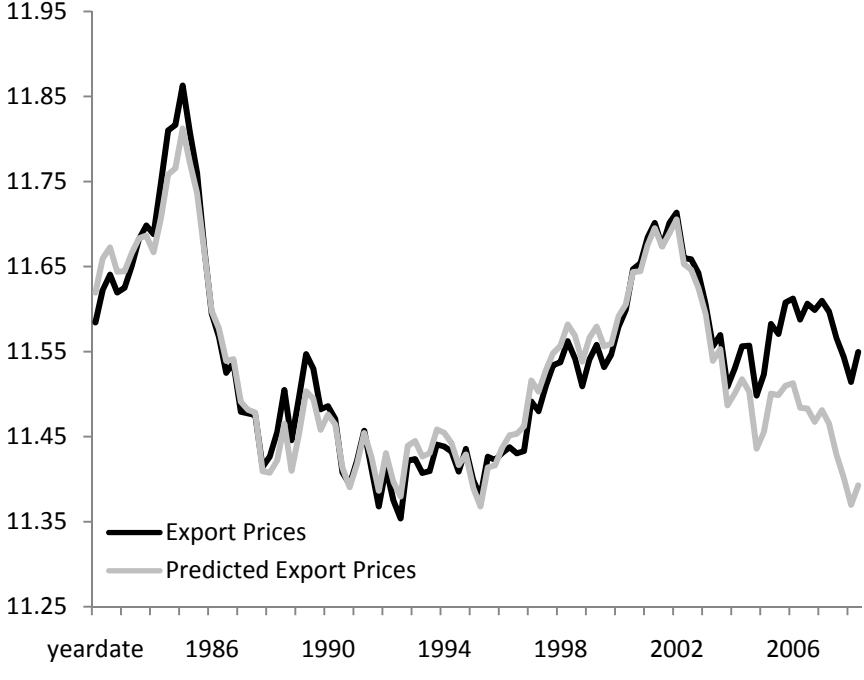

Figure III
U.S. Export Prices and the Real Exchange Rate

TABLE

Pricing to Market over Subsamples

Period	VECM	Dynamic Adj.
1982-2008	0.41	0.43
	(0.05)	(0.05)
1994-2008	0.46	0.32
	(0.08)	(0.08)

Theory

- How do we quantify product replacement bias in terms of observables?
- Model with product replacement

Prices and Exchange Rates: Theory

- Continuum of product lines j
- C_{jit} denoted units of product line j
- γ_{jit} denotes quality each unit in terms of utility
- Consumption aggregator for products from country i:

$$C_{it} = \left[\int_{N_i} (\gamma_{jit} C_{jit})^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

- Price index for products from country i

$$P_{it} = \left[\int_{N_i} \left(\frac{P_{jit}}{\gamma_{jit}} \right)^{1-\theta} dj \right]^{\frac{1}{1-\theta}}.$$

- γ_{jit} is unobserved to econometrician and BLS

PRODUCT REPLACEMENT: THEORY

Production function:

$$C_{jit} = \gamma_{jit}^{-1} F(K_{jit}, L_{jit})$$

$$\gamma_{jit} \begin{cases} \sim & \Gamma_t & \text{if product is replaced} \\ = & \gamma_{jit-1} & \text{otherwise} \end{cases}$$

Notation:

1. Frequency of product replacement: $z(s_t)$
2. Frequency of price change $f_j(s_t)$

Effective Prices and Quantities

- Effective consumption: $\hat{C}_{jit} = \gamma_{jit} C_{jit}$
- Effective price: $\hat{P}_{jit} = \gamma_{jit}^{-1} P_{jit}$
- Then we have:

$$C_{it} = \left[\int_{N_i} \hat{C}_{jit}^{\frac{\theta-1}{\theta}} dj \right]^{\frac{\theta}{\theta-1}}$$

$$P_{it} = \left[\int_{N_i} \hat{P}_{jit}^{1-\theta} dj \right]^{\frac{1}{1-\theta}}$$

$$\hat{C}_{jit} = F(K_{jit}, L_{jit})$$

- Totally eliminate γ_{jit} from the model
- Standard set of assumptions about demand and supply for "effective" units of output

Theory and Measurement

Measurement problem: γ_{jit} unobserved to BLS

(observed to consumers and producers)

- Ideal solution: Hedonics
- In practice: Matched model index
- Implicitly assumes: price flexibility for new goods same as for continuing goods (80-90% sticky prices)
- Alternative assumption: New goods get new prices

Product Replacement: Theory

Key assumptions:

- Prices are reset at time of product replacements
  - Firms set new prices when buyer, seller or product specification changes
  - Measurement issues
- Price changes at product replacement same as other price changes

Product Replacement: Theory

- Consider regression of Δp_{it} on aggregate variable Λ_{it}:

$$\Delta p_{it} = \alpha + B\Lambda_{it} + \epsilon_t$$

- Price index

$$\Delta p_{it} = \int \Delta \hat{p}_{jit} dj$$

- Decompose

$$B = \int \int B_j(s) dj ds$$

- Product type j and state s "regression":

$$\Delta p_{jit} = \alpha_{js} + B_j(s)\Lambda_{it} + \epsilon_{jt}$$

Product Replacement: Theory

- True coefficient: $B_j(s)$
- Measured coefficient: $B_j^{mm}(s)$
- Regression on only change observations: $B_j^{ch}(s)$
- Relationships:

$$B_j(s) = (f_j(s) + z(s) - f_j(s)z(s))B_j^{ch}(s)$$

$$B_j^{mm}(s) = f_j(s)B_j^{ch}(s)$$

- Bias:

$$B_j^{mm}(s) = \frac{f_j(s)}{f_j(s) + z(s) - f_j(s)z(s)} B_j(s)$$

Product Replacement Bias

- All products and states:

$$B^{mm} = \int \int \frac{f_j(s)}{f_j(s) + z(s) - f_j(s)z(s)} B_j(s) djds.$$

- Factor:

$$\frac{B}{B^{mm}} = \frac{\int \int B_j(s) djds}{\int \int \frac{f_j(s)}{f_j(s)+z(s)-f_j(s)z(s)} B_j(s) djds}$$

- Factor for constant f_j, z and B

$$\frac{B}{B^{mm}} = \left[\int \frac{f_j}{f_j + z - f_j z} dj \right]^{-1}$$

- Whole distribution of f_j matters
- $f_j/(f_j + z - f_j z)$ highly concave

LCP vs. PCP

Sign of bias depends on the currency in which price is rigid

- Local currency priced products (LCP):

  Appear less responsive to exchange rate

- Producer currency priced products (PCP):

  Appear more responsive to exchange rate

In practice:

- 93% of U.S. imports are LCP
- 98% of U.S. exports are PCP

MEASUREMENT

$$\frac{f_j}{f_j + z - zf_j}$$

Data

- Product-level BLS import and export microdata 1994-2007
- Approx. 1.5 million observations
- Exclude intrafirm transactions
- "Product" level data:
  - Auto part imported by Valeo Electrical Systems from BBI Inc.
  - Definition of a product includes "price determining factors"
  - Price determining factors: shipment size, seller/buyer, etc.
  - Product often a contract between a particular buyer and seller
  - New product not necessarily new to the world

Key Assumption

- Prices of newly introduced goods are “fresh” (newly reset)
- Prices of continuing goods are on average “stale”
  due to price rigidity

- Product replacement replaces “stale” prices with “fresh” prices
  without recording a price change
- Systematically misses part of response to exchange rate

How fresh is the first price?

- Many product replacements occur when firms cease buying or selling a product
  - Firms assumed to set new prices when buyer, seller or product specification changes (Carlton, 1986)
  - Approx. 60% of product replacements

- Reporting frictions imply that the prices of newly introduced products are more flexible than continuing products

Reporting Barriers

- Price data collected via optional survey
- New product initiation: Detailed interview
- Subsequent months: Repricing form
  - Easiest response: No change

How fresh is the first price?

Direct empirical evidence:

- Subsample: Products with exactly two price changes
- Regression:

$$\Delta p_{jk} = \alpha + \beta_S \Delta e_{jk,S} + \beta_{1Q} \Delta e_{jk,1Q} + ... + \beta_{6QL} \Delta e_{jk,6Q} + \epsilon_{jk},$$

- Run separately for first price change and second price change
- Run separately for imports and exports
- Fresh: β_{1Q}-β_{6Q} the same first and second price change
- Not fresh: β_{1Q}-β_{6Q} larger for first price change than second

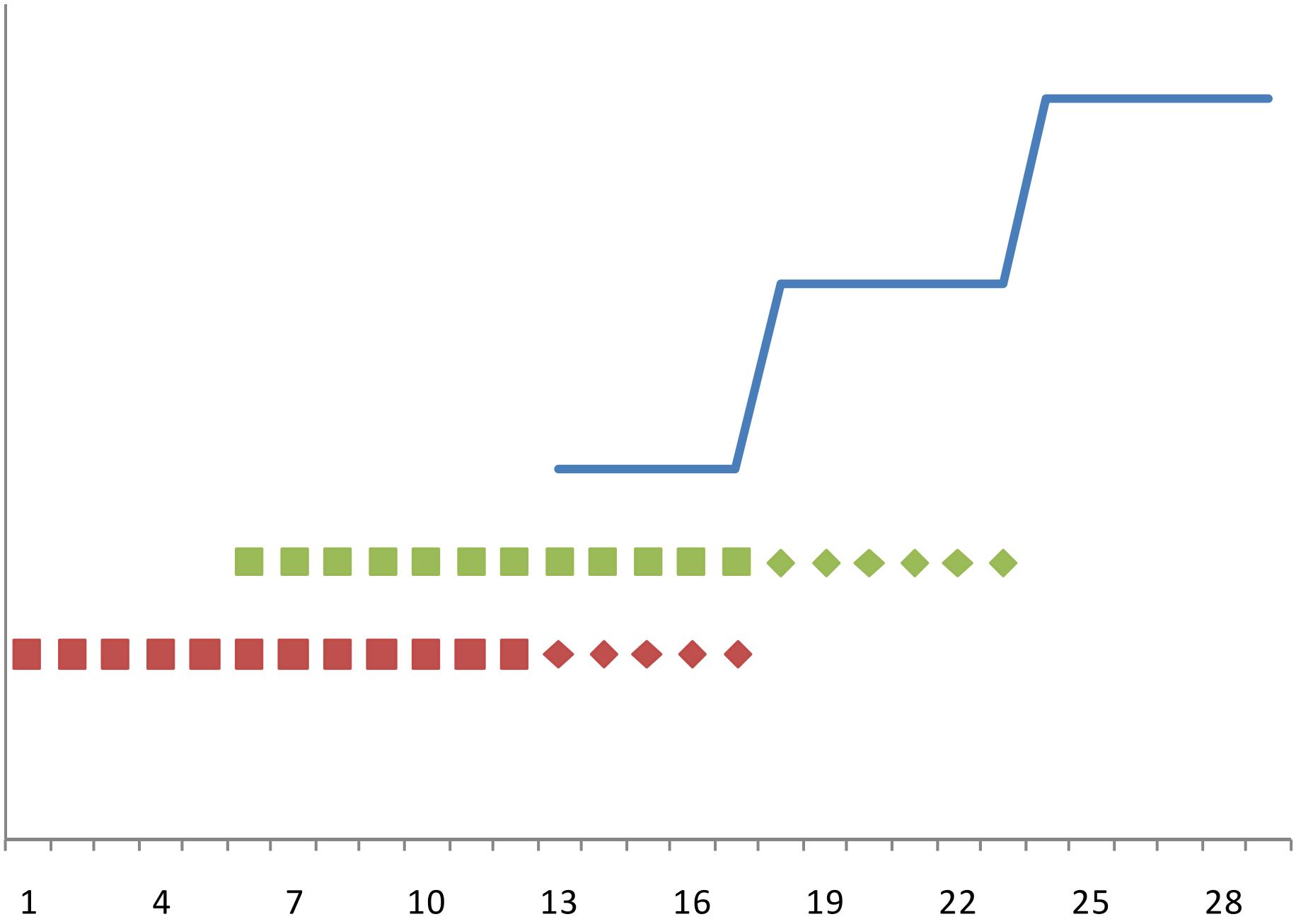
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TABLE

Price Change for First and Second Spell on Exchange Rate

	Imports		Exports	
	First Price Change	Second Price Change	First Price Change	Second Price Change
β_S	0.23	0.26	0.13	0.11
	(0.03)	(0.03)	(0.03)	(0.03)
β_{1Q}	0.19	0.18	0.03	0.14
	(0.05)	(0.04)	(0.07)	(0.06)
β_{2Q}	0.13	0.11	-0.06	-0.02
	(0.04)	(0.04)	(0.06)	(0.06)
β_{3Q}	-0.01	0.05	0.14	0.15
	(0.05)	(0.04)	(0.06)	(0.05)
β_{4Q}	0.07	0.09	-0.09	0.09
	(0.04)	(0.04)	(0.05)	(0.05)
β_{5Q}	0.05	0.04	0.19	0.08
	(0.04)	(0.04)	(0.06)	(0.06)
β_{6Q}	0.14	0.06	0.06	-0.01
	(0.05)	(0.04)	(0.07)	(0.06)
P-value (spell vs. 2nd Qrt)	0.052	0.002	0.008	0.059

TABLE

Price Change for First and Second Spell on Exchange Rate

	Imports		Exports	
	First Price Change	Second Price Change	First Price Change	Second Price Change
β_{S+1}	0.21	0.24	0.09	0.12
	(0.02)	(0.02)	(0.03)	(0.03)
$\beta_{2\text{-}4Q}$	0.06	0.09	-0.02	0.08
	(0.02)	(0.02)	(0.03)	(0.03)
P-value (spell vs. lags)	0.000	0.000	0.021	0.340

TABLE

Frequency of Price Change and Product Substitution for LCP Imports

	Freq. PC	Freq. Subs.	Weight
Animals & Animal Products	0.420	0.034	0.025
Vegetable Products	0.411	0.059	0.022
Foodstuffs	0.159	0.032	0.036
Mineral Products	0.120	0.091	0.007
Chemicals & AlliedIndustries	0.124	0.044	0.054
Plastics / Rubbers	0.186	0.045	0.038
Raw Hides, Skins, Leather, & Furs	0.060	0.043	0.019
Wood & Wood Products	0.338	0.038	0.080
Textiles	0.053	0.066	0.089
Footwear / Headgear	0.047	0.047	0.046
Stone / Glass	0.221	0.025	0.070
Metals	0.215	0.052	0.064
Machinery / Electrical	0.095	0.054	0.204
Transportation	0.087	0.052	0.143
Miscellaneous	0.046	0.044	0.103
Weighted Average	0.141	0.048	1.000
Weighted Median Across Industries	0.095	0.052	1.000

Heterogeneity in Frequency of Price Change

- Constant hazard of price change for each product j:

$$f_j \sim \text{Beta}(a, b)$$

- Denote product j's lifetime by n_j
- Denote number of price changes for product j by x_j
- Constant hazard implies:

$$x_j \sim \text{Bin}(n_j, f_j)$$

- We estimate a and b by maximum likelihood

TABLE

The Distribution of Price Changes and Substitutions

	Imports		Exports	
	LCP	PCP	LCP	PCP
Fraction of Imports/Exports	0.926	0.074	0.029	0.971
Mean Frequency of Price Change	0.141	0.074	0.087	0.117
Median Frequency of Price Change	0.067	0.036	0.035	0.063
Mean Frequency of Substitutions	0.048	0.047	0.057	0.052
Distribution of the Frequency of Price Change				
a	0.50	1.07	0.76	0.53
	(0.01)	(0.07)	(0.04)	(0.01)
b	3.65	19.12	7.76	4.60
	(0.06)	(1.32)	(0.83)	(0.11)

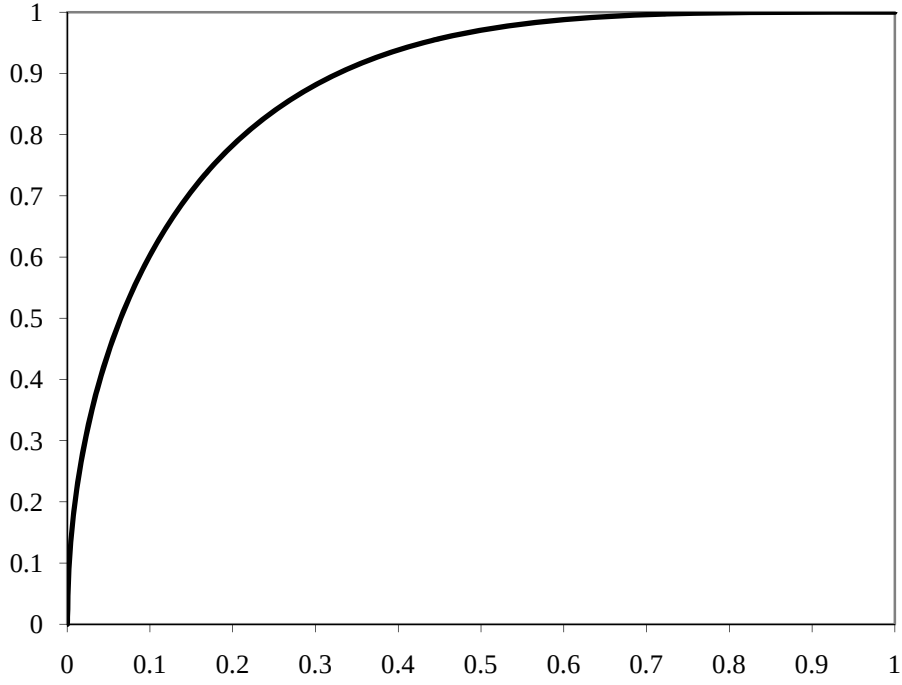

Figure IV
Cumulative Probability Distribution of Beta(0.50,3.65)

Heterogeneity in Pass-through

- Gopinath and Itskhoki (2008) argue that low frequency of price change products have low long-run pass-through
- Heterogeneity in desired pass-through affects product replacement bias:

$$\frac{B}{B^{mm}} = \frac{\int B_j dj}{\int \frac{f_j}{f_j + z - f_j z} B_j dj}$$

- Assume low freq. products have LR pass-through equal to 65% of high freq. products (Gopinath and Itskhoki, 2008)
- Alternative explanation: spurious price changes

TABLE

Product Replacement Bias

	LCP	PCP
No Heterogeneity in Comovement		
Imports	1.84	2.14
Exports	1.95	1.96
With Heterogeneity in Comovement		
Imports	1.74	2.14
Exports	1.90	1.86

TABLE
Pricing to Market

	Imports	Exports
Measured:		
VECM	0.41	0.87
	(0.05)	(0.06)
Dynamic Adjustment	0.43	0.85
	(0.05)	(0.05)
Levels	0.36	0.86
	(0.02)	(0.03)
Adjusting for Product Replacement Bias:		
No Heterogeneity in Comovement	0.70	0.78
With Heterogeneity in Comovement	0.66	0.79

Conclusions

- Product replacement bias distorts pass-through by a factor of roughly 2
- Adjusted estimates:
  - Imports: 0.7 (rather than 0.4)
  - Exports: 0.8 (rather than 0.9)
- Degree of pricing to market
  - More symmetric
  - More moderate for imports

Conclusions: Terms of Trade

Conventional measures:

- 1% depreciation
- Dollar price of imports rise by 0.2-0.4%
- Dollar price of exports rise by 0.1
- Terms of trade deteriorates by 0.1-0.3%

Adjusting for product replacement bias:

- 1% depreciation
- Dollar price of imports rise by 0.7%
- Dollar price of exports rise by 0.2
- Terms of trade deteriorates by 0.5%

Conventional measures understate volatility of terms of trade by factor of 1.7-5

Further Implications

1. Applies to consumer prices:
   - Could generate artificially volatile real exchange rate
2. May also apply to unit value indices: price comparisons often dropped due to lack of data for previous period
3. Affects responsiveness of trade quantities to exchange rates
   - Trade elasticities biased away from one
4. May explain differences in measured import price pass-through for developed vs. developing countries